Original Research Article

A Geotechnical and Environmental Risk Assessment of Two Gully Erosion Sites in Nkwoegwu Autonomous Community, Umuahia North LGA of Abia State, South-Eastern Nigeria.

Abstract

It was reported that the sister erosion sites have caused serious environmental hazards and problems to the host communities for about 30 years with little or no control measures put in place. Soil samples were collected from the active gully walls and their geotechnical properties including sieve analysis, atterberg limits, compaction, moisture content, bulk density and shear strength characteristics were measured in the laboratory and analyzed. Results of the laboratory measurements indicated the soils at the gully sites are predominantly sandy whereas the composition of soil at different sites varied as: Site A – (Clay and Silt – 29.48%, Sand – 69.01%, Gravel – 1.51%); Site B – (Clay and Silt – 41.71%, Sand – 57.54%, Gravel – 0.75%). The liquid limit values are 26 and 2 per cent, plastic limit 19 per cent while the plasticity index values are 7.0 and 6.0 per cent respectively. The maximum dry density (MDD) values were 1.99 and 2.02 mg/m^3. The optimum moisture content (OMC) values are 12.1 and 13.3 per cent; CBR values being 32 and 4 per cent respectively. The moisture content of the erosive soil samples was 8.5 and 11.2 per cent. The result for the bulk density gives 1.38 and 1.28 g/cm^3 respectively, while the shear strength values comprising cohesion, C, and angle of internal friction, Φ, gave their C to be 34 N/m^2 each and Φ of 14° and 16° respectively. The soil materials was therefore, mostly loose sands with low percentage of silt/ clay fractions, and hence low cohesion that are vulnerable to agents/ factors of gully erosion such as rainfall, slope of land-surface and human activities. The topographical survey showed that the gully sites are the lowest points in the area which is also the direction of drainage. The total surface runoff from the area of study was estimated to be 384000 m^3 per day. Environmental risks such as loss of arable land and threat to lives and properties were identified as well.

Keywords: Drainage Analysis, Environmental Risk Assessment, Geo-hazards, Gully Erosion, Soil Tests,

INTRODUCTION

One of the most contemporary environmental issues today is the problem of erosion which remains a threat to humanity. The main agents of erosion are water, wind and gravity. Erosion is considered a natural process but it is often intensified by human land use practices.

In the past three decades, gully erosion has been an issue of concern in the southeastern part of Nigeria and Abia State in particular. Gully erosion is an obvious form of soil erosion consisting of an open, incised and unstable channel generally more than 30 centimeters deep (Akpokodje, 2001). It occurs where surface water flow has become trapped in a small concentrated stream and begins to erode channels in the ground surface. Gully erosion is a highly visible form of soil erosion that affects soil productivity, restricts land use and can threaten roads, fences and buildings (Imasuen *et al*., 2011). The menace of gully erosion in Nkwoegwu, Umuahia ranges from loss of arable land to road failures which could eventually lead to source of disease pathogens, death traps for road users and in some cases serves as hideouts to criminals and bandits. Soil eroded from the gullies can cause siltation of fence lines, waterways, road culverts, dams and reservoirs. Suspended sediments, which may have attached nutrients and pesticides, can adversely affect water quality. These fines, colloidal clay particles remain in suspension and may clog groundwater aquifers, pollute watercourses and affect aquatic life. Controlling gully erosion can be difficult and expensive. The quality and nature of soil are key to controlling the menace of gullies. However, controlling gullies over large areas of poor soils may be impracticable. Thus, understanding the nature and geotechnical properties of soils will help in the identification of environmental problems and solutions associated with the two Gully erosion sites in Nkwoegwu in communities, Umuahia North, Abia State, South- Eastern Nigeria with the possibility of establishing suitable control measure.

Site A: Signboard, Nkwoegwu	Site B: Umuakam, Nkwoegwu

Geological and Topographic map of the study area

Study Area

Two (2) gully sites namely Signboard (Site A) and Umuakam (Site B) in Nkwoegwu community of Umuahia North LGA, Abia State, Nigeria were purposively selected for study. The two sites are located within Latitude 5°33´ to 5°35´N and Longitude 7°27´ to 7°29´E and are known to be in existence for over 30 years.

The gully at Signboard (Site A) was 57ft deep, 15m wide and 22m long whereas it was 21 m wide, 74m long and 54ft deep at Umuakam (Site B).

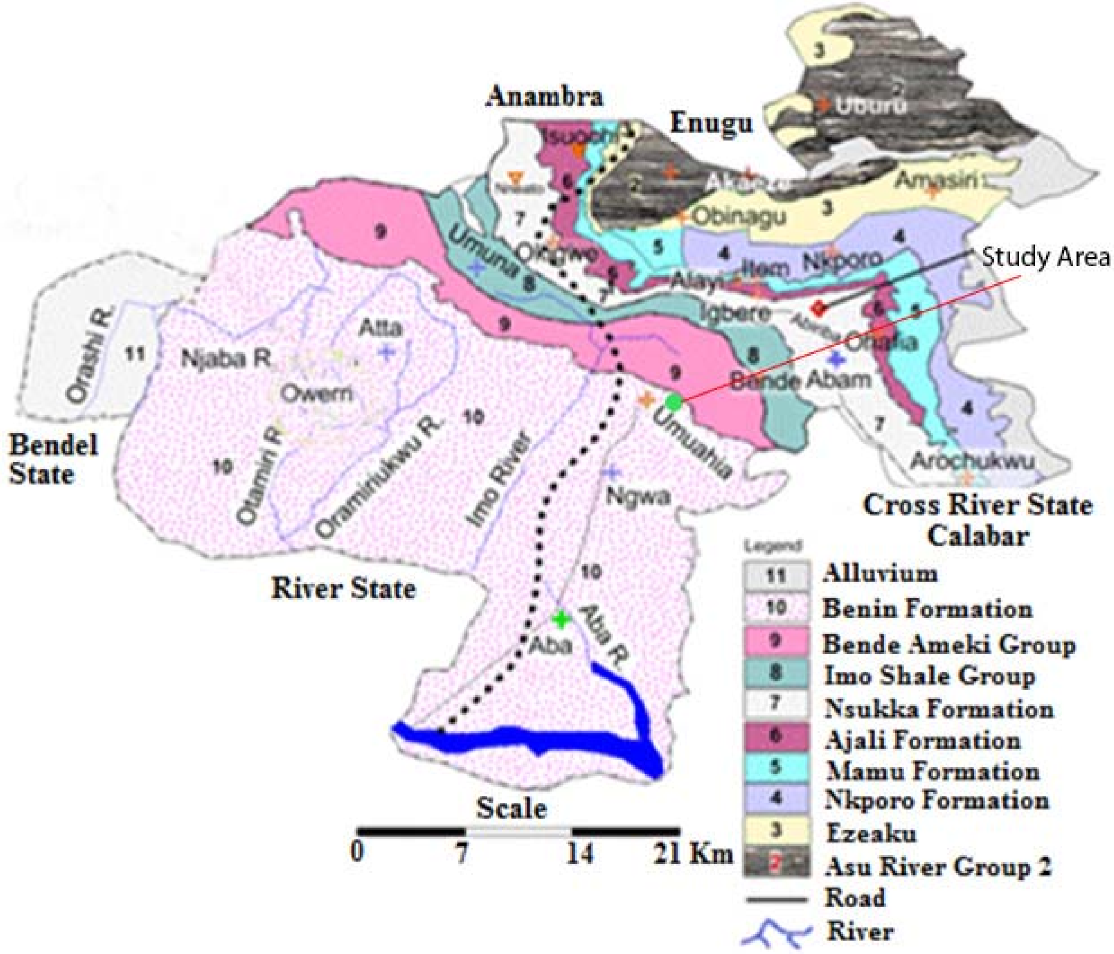

Fig 1: Geologic map of Imo River Basin Showing the geology of the study area

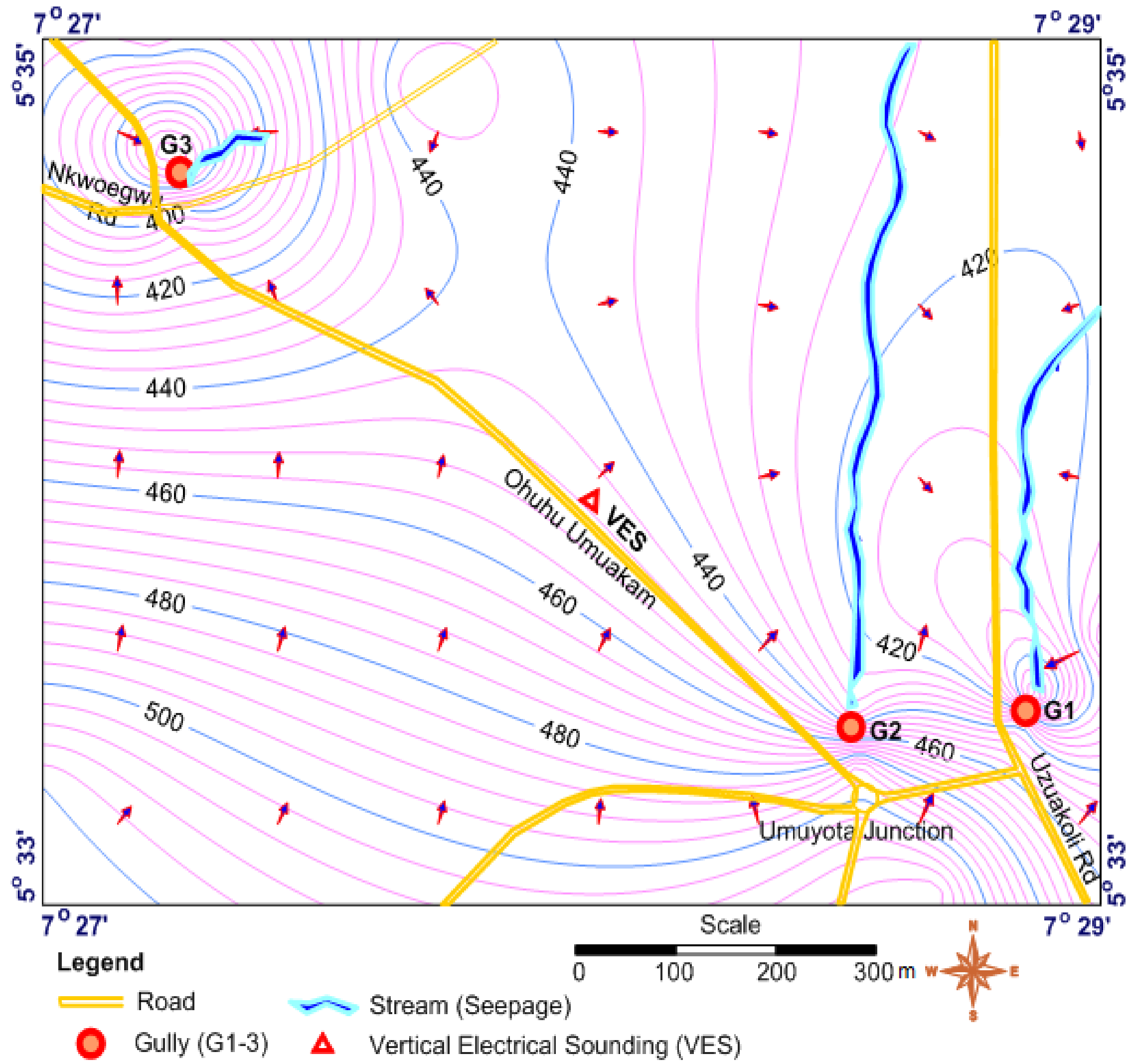

Fig 2: Topographic Map of the Study Area

MATERIALS AND METHOD

Sample Collection

Soil investigation which comprised field studies and laboratory analyses was undertaken. The field investigation for soil data collection involved sampling and measurement in the study area. Soil samples were collected from the gullies at various depths ranging from 21.4 to 20.3 m. The technique for sample collection was in according to Spangler and Handy (1973). A total of Four (4) soil samples were collected and packaged in polythene bags for laboratory analyses.

Laboratory Analysis

A series of geotechnical tests were carried out on the soil samples obtained with the use of hand auger and Core penetration sampler, these includes Grain size analysis, Atterberg limits, Moisture content, Bulk density, Compaction and Shear strength test and were performed in accordance with procedures specified by the American Society for Testing Materials (ASTM) and the British Standard Methods for testing soils for Civil Engineering purposes (B.S., 1377-1990). The laboratory tests were conducted to determine soil index properties.

RESULTS AND DISCUSSION

Table-1 showed summary of data that were used in plotting grain size or particle size distribution of the soils in the study area. The summary of geotechnical properties of soil samples in the study area presented in Table 2. Result of geotechnical investigation and laboratory analysis showed that the soil in the Site A contained majorly Clay & Silt – 29.4 per cent, Sand – 69.01 per cent and Gravel – 1.51 per cent indicated that the soils contained very small amount of clay which normally serves as a binding material hence loosely held together. The result of Site B showed an appreciable increase in the number of fine fractions as Clay & Silt – 41.71 per cent , Sand – 57.54 per cent, Gravel – 0.75 per cent. Nevertheless, the result of the sieve analysis indicated that the soil of the study area was predominantly of sand, as described in the geology of the area (Bende-Ameki formation). According to Okengwo, *et al*. (2015), the low amount of fine in the underlying soil strata, which would have cemented the sand particles, implies in-sufficient binding materials and thereby suggests high susceptibility of the underlying soil materials to erosion. This trend suggests a decrease in cohesion and resistance to soil cracking. Ofomata (1981) also observed that areas of high susceptibility correspond to geological regions of weak unconsolidated sandy formations while least susceptible areas are within the consolidated tertiary to recent sediments. He also noted that in South-eastern Nigeria, the classical gully sites were located in the False-bedded sandstone, Coastal Plain sands, Nanka Sands and the Bende-Ameki Formations. Atterberg limit test is an important soil test in environment and foundation studies. It gives an indication of the consistency limits of the soil. Soils from Sites A and B recorded a low plasticity index of 7 and 6 respectively. The low values of plasticity index indicated that they are relatively unstable over a wider range of moisture content. Akpokodje, 2001 observed in his study the low values of plasticity index, could be attributed to small amount of fines in the samples and indicates that the soil is non-cohesive and has a low plasticity. So due to non-cohesive nature of the soils in the area accounts for the gully erosion problems.

The compaction result showed that the maximum dry density (MDD) of Sites A and B to be 1.99 and 2.02 g/cm^3 respectively. The respective Optimum Moisture Contents (OMC) was 12.1 and 13.3 per cent. The low values of the (MDD) implied that the soils are generally not compacted and are loosely bound. The conditions for the soil to be compacted, it must have low permeability, low water absorption and undergo minimal settlement especially for engineering purposes. The recorded values are within the range as reported by Okunlola, *et al*. (2014) and O' Flaherty (1988). Similar findings were noticed by Ishaku *et al*., (2002). The CBR values 32 per cent found for Site A and 4 per cent for Site B. This indicated that the soils from Site A can be used for remediation purposes while that of Site B for fill material and totally be excavated. Moisture content registered low values for both the sites. The low moisture contents of the subsurface soils lead to high capacity for water retention during rainfall which eventually caused breakdown of the grain-to-grain forces that existed in the soil ultimately enhanced soil erosion (Okagbue and Ezechi, 1988).

Bulk density was recorded 1.38 and 1.28 g/cm^3 for Site A and Site B. Bulk density of soils is known to reflect the soil's ability to function for structural support, water and solute movement and soil aeration. Hence, the recorded values of the bulk density of the soil samples supported movement of water. This indicated that soils of study are able to easily erode due to the transmissibility of water within its pore spaces. For sandy soils, the ideal bulk density for plant growth should be less than 1.60 g/cm^3. Hence, planting of vegetative cover within the gullies would be a veritable means of controlling the gully.

The result of the tri-axial shear test for both sites gave the Cohesion as 34 kn/m^2 for both sites while the angle of internal friction was 14° and 16° for site A and B respectively. These values found low when compared with 65Kpa cohesion and 26° angle of friction classified as average by Alao and Opaleye (2011) thereby offered little resistance to the effect of both surface water and subsurface flow. It is an established fact that Shear strength of soils is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain. Hence, the higher the stress it can sustain, the better the soil could be used for engineering processes.

Table 1: Geotechnical properties of soil samples in the study area

Parameters / Location	Site A: Signboard, Nkwoegwu	Site B: Umuakam, Nkwoegwu
Depth (m)	21.4	20.3
Length (m)	22	74
Width (m)	15	21
Distance from road (m)	8	1.4
Distance to the nearest building	11	15
L.L.	26	25
P.L.	19	19
P.I.	7	6
Gravel (%)	1.51	0.75
Sand (%)	69.01	57.54
Silt (%)	29.48	41.71
Bulk Density (g/cm^3)	1.38	1.28
Max. Dry Density (g/cm^3)	1.99	2.02

OMC (%)	12.1	13.3
MC (%)	8.5	11.2
CBR (%)	32	4
Cohesion (N/m^2)	34	34
Angle of Internal Friction (Degrees)	14	16

SIEVE ANALYSIS

The graphs obtained from sieve analysis for both the sites presented as below:

CLAY %	SILT %		SAND: %	GRAVEL %	
COMBINED CLAY & SILT		29.48%	69.01%		1.51%

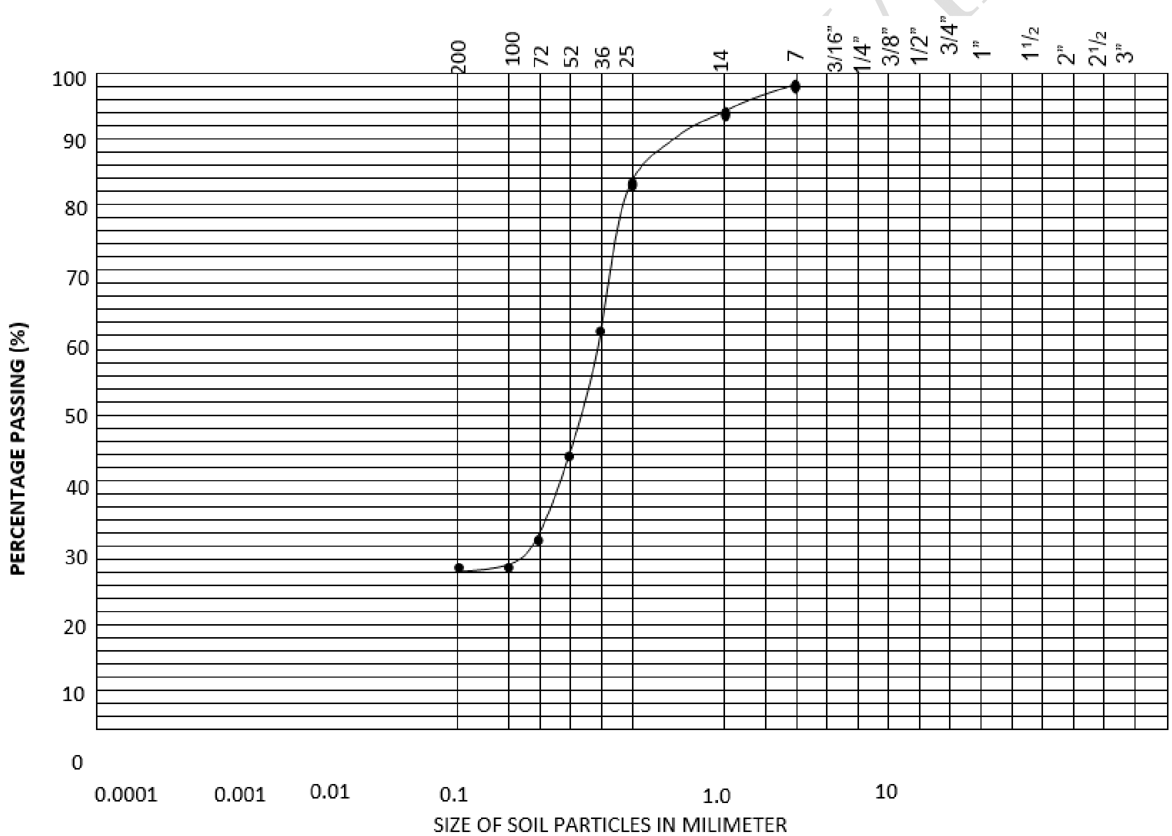

Fig. 3: Graph of Sieve Analysis for Site A

In Site A, the percentage of soil aggregates was found as Clay & Silt 29.48 per cent , Sand 69.01 per cent , Gravel 1.51 per cent while for Site B it was recorded as Clay & Silt 41.71 per cent , Sand 57.54 per cent, Gravel 0.75 per cent (Fig. 3 and 4).

CLAY %	SILT %	SAND: %	GRAVEL %	
COMBINED CLAY & SILT	41.71%	57.54 %		0.75 %

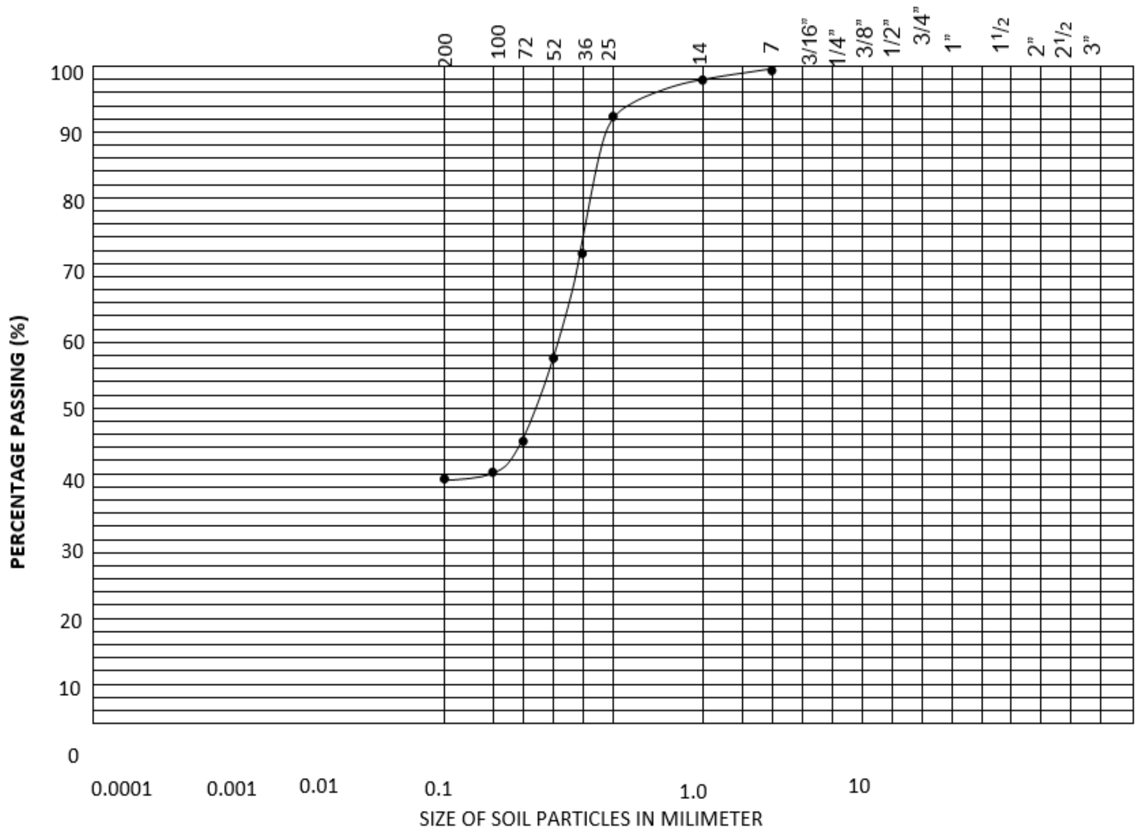

Fig. 4: Graph of Sieve Analysis for Site B

ENVIRONMENTAL ASSESSMENT

Topographic survey of the area indicated that the gully area has sloppy terrain. Hence, runoff flowed towards the direction of the gullies before entering Isiokata River. Morphological data as presented in Table 1 showed that the average depth, top width and length of the gully were: 21.4, 22. 15 (for Site A) and 20.3, 74, 21 (for Site B). The volume of runoff was 384,000 cubic meters of water which contributing to the gully expansion due to improper termination of the side drains, designed to channel runoff and waste water produced from the surrounding environment directly to the gully head. This has led to scouring, undercutting and eventual collapse of the drains. It was also observed that gully head had eaten up almost half of the road leading to Umuakam village. The gully head at Umuakam was almost eating up the road leading to the community as it had taken up 1.4 m of the road. The gully head at Signboard is 8m from the road which was tarred. The distance of the active part of the gully at Umuakam to the nearest building is 15m while that of Signboard is 11m. Due to huge volume of soil lost by virtue of these two gully sites, it was evidently clear that a substantial amount of arable land had been lost which pose a serious threat to food security. The gully sites could be a possible hideout for hoodlums.

CONCLUSION

The study evaluated the factors responsible for the development of gully sites at Nkwoegwu, Umuahia, North LGA by utilizing information from geotechnical investigation. The causative factors responsible for the development of gully at Nkwoegwu Community was noticed as : the low amount of fines in the soils, improper termination of drains, topography, and human activities. All these contributing to the gully expansion due to improper termination of the side drains, designed to channel runoff and waste water produced from the surrounding environment directly to the gully head. Some soil conservation techniques must be employed to curb this problem in future.

RECOMMENDATIONS /CONTROL MEASURES

The study indicated that the subsurface geology of the study area was prone to erosion due to its non- cohesive nature. The gully development increased once the underlying cohesionless soil is penetrated. Thus, an adequate drainage analysis should be put in place, considering the topography of the area. For control measures, model propounded by Nwankwor, *et al*,

(2015) must be adopted. The conceptual road model which is applicable to both tarred and earth roads, should have its boundaries densely grassed. This reduces the amount of runoff reaching the drains through interception, temporary detention and induced infiltration of runoff. It was found that reduced runoff into the drains makes the net runoff volume less destructive and easier to manage during the eventual flood water termination and diversion stage.

REFERENCES

ASTM International (2006). Standard practice for classification of soils for Engineering purposes (Unified soil classification system) Pp12.

Akpokodje, EG (2001). Introduction to Engineering Geology. Pam Unique Publications. PP. 259.

Alao, DA and Opaleye, TS, (2011): Geotechnical analysis of slope failure of a Kaolin quarry at kurra, Jos of North-central Nigeria. *Nigerian Mining and Geosciences Society Journal*, 1 (2) 87-102

British Standard Institution (1990). Methods of Test for soils for Civil Engineering Properties

(BS 1377) British Standard Institutions London, UK. P143

Ishaku, JM, Adeleke, JID and Negro, SS (2002). The Hydrogeological and Geotechnical characteristics of Rock Materials that Aid Gully Erosion in Lassa Area of Borno State, North Eastern Nigeria, *Water Resources – Journal of Nigeria* : **13**, 53.

Nwachukwu, MA and Osoro, E. (2013). Assessment of Environmental Hazards: Linking borrow pits, gully erosion and pavement failure. *Journal of Civil Engineering and Construction Technology,* 4(6): 199-210.

O'Flaherty, CA, (1988). Highway Engineering, Vol. 2. *Edward Arnold Publishers*, London, Uk,

Ofomata, GEK (1981). Acrtual and Potential erosion in Nigeria and measures for control. *Soil Science Society of Nigeria Special Monograph 1*, 151-165.

Okagbue, CO and Ezechi, JO (1988). Geotechnical Characteristics of Soils Susceptible to Severe Gullying in Eastern Nigeria, *Bulletin Int. Assoc. Eng. Geology No. 38, PP. 111*

Okengwo, ON, Okeke, OC, Okereke CN and Paschal A C (2015). Geological and Geotechnical Studies Of Gully Erosion at Ekwulobia, Oko and Nanka Towns, Southeastern Nigeria. *Electronic Journal of Geotechnical Engineering vol.* ***20****:1*

Okunlola, IA, Abdulfatai, IA, Kolawole, LL and Amadi, AN. (2014). Geological and Geotechnical Investigation of Gully Erosion along River Bosso, Minna, North Central Nigeria. *Journal of Geosciences and Geomatics, 2(2), 50-56.*